to that of the earth, it will fall in about one mile in the first year. If it continues to describe a nearly circular spiral, it will fall in less and less each revolution, but the revolutions take less and less time, and in equal times it will fall in more and more. Such a sphere will reach the sun in something of the order of 45,000,000 years. But the rate of falling in is inversely as the radius, so that a sphere 1/1000 cm. in diameter will fall in 1000 miles in the first year, and will reach the sun in 45,000 years.

There is no doubt that there are such bodies in our system. We have clear evidence of their existence when they perish as shooting stars in our atmosphere. Also there seems no way to avoid the conclusion that they are all spiralling in to the sun and will ultimately reach him unless their career is cut short by some intervening planet. How, then, are we to account for their existence in our system to-day? Whatever limit we may assign to the age of the earth as a habitable globe, we must assign to the sun some vast number of millions of years, vast enough to have allowed him long ago to draw to himself all the specks of dust in his system. How is the supply renewed? Is interstellar space inhabited by scattered meteorites? Are they brought in by comets which have become disintegrated? And so light pressure raises once more an old and still unsolved problem.

A NEW TRYPANOSOME PARASITIC IN HUMAN BEINGS.[1]

THE terrible mortality caused by sleeping sickness in Africa, and the knowledge that this deadly disease is caused by a species of trypanosome, has directed the attention of the general public, as well as of scientific and medical men all over the world, to these blood-parasites. The frequent occurrence of trypanosomes in the blood of vertebrate animals of all classes has long been known to zoologists, but this fact was regarded as little more than a scientific curiosity until Bruce, scarcely fifteen years ago, showed that a species of trypanosome, since named after him (*Trypanosoma brucii*), was the cause of the dreaded tsetse-fly disease of domestic animals in Africa, and followed this up by his discoveries, in the present century, with regard to the nature and transmission of sleeping sickness.

No little sensation was created, therefore, when it was announced by Chagas about a year ago[2] that he had discovered a new species of trypanosome, named by him *Trypanosoma cruzi,* in human blood in Brazil. A full account of this parasite, its development, and mode of transmission, has now been published by Chagas, with numerous illustrations, and it proves to be a form no less interesting from the purely zoological than from the medical standpoint.

The manner in which this parasite was discovered is remarkable. Chagas found that in the province of Minas Geraes the houses, especially the thatched huts of the poorer classes, were infested by bugs (Fig. 1) of the species *Conorhinus megistus,* voracious blood-suckers of large size and nocturnal habits, responsible for much loss of sleep, as well as of blood, to the unfortunate inhabitants. Some of these bugs were collected and brought to Rio de Janeiro, where they were dissected and examined in the laboratory of the Instituto Oswaldo Cruz, and were found to contain in their digestive tracts numerous flagellate organisms resembling in form and structure the genus Crithidia. When such bugs were allowed to feed on experimental animals, namely, marmosets (*Callithrix penicillata*) and guinea-pigs, they infected them with trypanosomes, to the effects of which the marmosets succumbed in about two months, the guinea-pigs in five to ten days. After this surprising result, Chagas returned to Minas Geraes and examined the blood of human beings in the zone infested by the bugs, and found several cases of human beings infected with similar trypanosomes. Thus the course of the discovery of this parasite has been the exact opposite to that of the progress of our knowledge of sleeping sickness; there the disease was thoroughly known long before it was found to be caused by a trypanosome, then the mode of transmission was discovered, and the complete life-cycle of the parasite has not yet been worked out; here the transmitting insect was first known, then the parasite itself was discovered, and, last of all, it was found to occur in human blood, with the result that the life-cycle of the trypanosome has been investigated in considerable detail, but very little is known of its effects in their clinical aspect.

The few cases of infected human beings observed by Chagas have not been followed out by him to their end as yet. He finds the effects of the parasite to be most marked, however, in children, amongst whom it appears to cause severe mortality. The chief symptoms are anæmia, œdema, general or localised, enlargement of the lymphatic glands and of the spleen, and functional disturbances, especially of the nervous system, leading in some cases to imbecility. A tendency to arrest of development, resulting in pronounced infantilism, was also noticed. According to information collected, the fatal termination of the disease was frequently attended by convulsions, regarded locally as the cause of death, and sometimes by dropsy in the last stages.

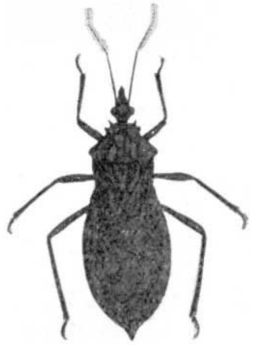

FIG. 1.—*Conorhinus megistus,* Burm., ♀.

The life-cycle of the parasite, as described by Chagas, shows some peculiarities not yet known in any other species of trypanosome. In the vertebrate host it exhibits three phases, which may be termed conveniently the adult, the multiplicative, and the growth phase respectively.

In the adult phase, the organism is free in the blood-plasma, and has the typical trypanosome-structure (Fig. 2, *a*). It shows, however, a dimorphism which Chagas regards as sexual. One form, regarded as male, is more slender, with a larger kinetonucleus and a more elongated trophonucleus; the other, regarded as female, is broader, with smaller kinetonucleus and rounded trophonucleus.

These adult trypanosomes in the peripheral blood were never observed to multiply by fission, a fact which the author seems to consider remarkable, doubtless from the standpoint of studies upon pathogenic trypanosomes, though it may be pointed out that the same is true of the common trypanosomes of vertebrate animals, especially those of birds and fishes. Chagas has discovered that the multiplication takes place by a process of multiple fission or "schizogony" in the lung. Hence he founds provisionally a new genus, Schizotrypanum, for this species. It remains to be seen how far such schizogony is peculiar to this parasite. The only salient difference between the multiple fission of *Schizotrypanum cruzi* and that of the common *Trypanosoma*

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[1] "Nova tripanosomiaze humana." By C. Chagas. Memorias do Instituto Oswaldo Cruz I., 1009. Pp. 159-218; plates ix-xiii and 10 text-figures. (Portuguese and German text.)

[2] See the Bulletin of the Pasteur Institute for May 30, 1909, p. 453.

lewisi of rats, is that in the latter the flagellum is retained, as a rule, and in the former is always lost, during the process. In *S. cruzi* there appears to be an alternation between periods of multiplication with schizogony in the lungs, with adult free trypanosomes occurring sparingly in the blood, and periods in which the peripheral blood contains numerous trypanosomes. In the case of experimental animals, it was found, as a rule, that at the time of death trypanosomes were very scanty in the blood, while schizogony was proceeding actively in the lung.

The trypanosome, when about to undergo multiplication, first throws off the flagellum and undulating membrane; it may or may not lose its kinetonucleus at the same time. It then curls up (Fig. 2, *b*), and contracts into a rounded mass, the schizont (Fig. 2, *c*), after which the trophonucleus and the kinetonucleus, also, if present, divide each three times to form eight small nuclei of one or both kinds (Fig. 2, *d*). The protoplasmic body then divides up within its own skin (periplast) into as many parts, termed by Chagas merozoites (Fig. 2, *e*). Each merozoite contains either a single trophonucleus, or a kinetonucleus in addition. The generation with a persistent kinetonucleus is regarded by Chagas as male, that without any such body as female. Although the author insists on interpreting these and other differences as sexual, it should be noted that no sexual behaviour has been observed in any part of the life-cycle of the parasite.

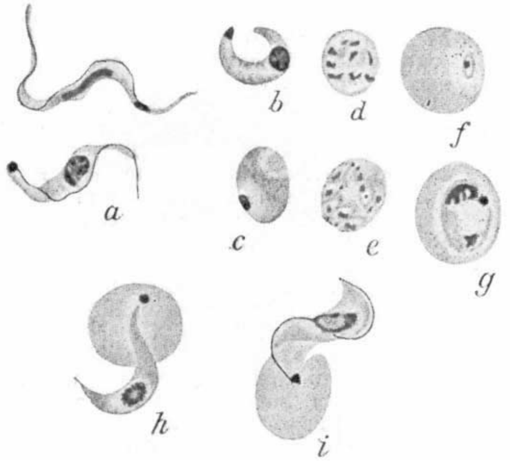

FIG. 2.—*a–i*, Phases of *Schizotrypanum cruzi* in vertebrate blood. *a*, the two forms of the adult trypanosome, "male" (upper) and "female" (lower), from human blood; *b*, preparations for schizogony; *c*, schizont; *d*, division of the nucleus of the schizont; *e*, division of the schizont into eight merozoites; *f*, merozoite in a blood-corpuscle; *g*, intra-corpuscular phase in late stage of growth; *h*, similar phase escaping from the corpuscle, the flagellum not yet formed; *i*, similar phase, the flagellum in process of formation.

The tiny merozoites are stated to escape singly from their envelope and to penetrate into red blood-corpuscles (Fig. 2, *f*), in which they grow into the adult form (Fig. 2, *g, h*). In those merozoites which are without a kinetonucleus, this body arises by division of the single nucleus present. The flagellum and undulating membrance appear to be formed when the organism is full-grown, sometimes not until it has escaped from the blood-corpuscle (Fig. 2, *h, i*). It is remarkable, however, that Chagas does not figure any intracorpuscular phases intermediate in size between the very smallest and those which are practically full-grown; and it must be said that many of his figures of the later growth-phases are not at all convincing as to the parasite being really within the corpuscle. With completion of growth and liberation from the corpuscle, the adult phase of the free trypanosome is reached.

On the ground that *Schizotrypanum cruzi* differs from all known trypanosomes in undergoing multiplication by schizogony, and in the possession of an intracorpuscular phase, Chagas regards it as a form connecting the trypanosomes and the Hæmosporidia (malarial parasites and allied forms), and supporting the union of these two groups in systematic classification. This view raises questions which cannot be discussed in a brief space.

By experiments on the transmission, Chagas found convincing evidence that the parasite goes through a developmental cycle, with a minimum duration of eight days, in the bug. Until this cycle is complete the bug is not infective. It is a point of great interest that, while bugs collected in human dwellings and bugs fed in the laboratory on infected marmosets transmitted the infection, he was never able to render bugs infective by feeding them on infected guinea-pigs. Chagas is of opinion that a certain condition of the parasite is necessary to produce infectivity in the bug, and that the requisite conditions are furnished by the blood of human beings or marmosets, but not by that of guinea-pigs. Experiments to prove transmission of the parasite through the egg of the bug gave entirely negative results in all cases.

Phases in the development of *Schizotrypanum cruzi* in the invertebrate host are described by Chagas from bugs bred in the laboratory and fed on infected animals. The parasites begin to undergo a change in the stomach of the bug about six hours after feeding (Fig. 3, *a, b, c*); they lose their flagellum and contract into rounded forms which multiply actively by fission (Fig. 3, *d*). After a period of multiplication, the rounded forms become pear-shaped, and develop a flagellum at the pointed end (Fig. 3, *e, f*); thus are produced flagellates of the Crithidia type (Fig. 3, *g, h*), which pass on from the stomach into the intestine, and there multiply rapidly by fission. As a result, the intestine becomes peopled by a swarm of crithidial forms, the characteristic condition of the infected bug. In a few instances Chagas found trypanosome-like flagellates in the body-cavity and the salivary glands (Fig. 3, *i*), and he regards these trypaniform individuals as the last phase in the development of the parasite in the bug, that is to say, as the form in which the parasite is inoculated into the vertebrates by the invertebrate host.

It should be noted here that the three principal forms which the parasite assumes in the bug, namely the rounded, crithidial, and trypaniform types, are found by Chagas to occur also in artificial cultures on blood-agar, and to succeed each other in the same order. This parallelism indicates that these forms represent the natural developmental cycle of the parasite in the invertebrate host; that the rounded and especially the crithidial forms represent the multiplicative phase whereby the parasite establishes itself in the bug, while the trypaniform individuals represent the propagative phase destined to infect new hosts. Chagas, however, interprets the facts observed in a different manner. He regards the crithidial forms as the end-product of an atavistic degeneration of the parasite, a mere culture-phase which does not develop further, and is of no importance for the transmission to the vertebrate host and the continued propagation of the parasite. On the other hand, he attaches great importance to two forms observed by him in the bug but not found in the artificial cultures, namely, encapsuled forms (Fig. 3, *j*), which he believes to represent zygotes, although no conjugation has been observed, and certain forms which he interprets as schizogony in the intestine of the bug. According to Chagas, the true infective cycle of the parasite in the bug is comprised in four stages:—(1) the encapsuled "zygotes"; (2) the schizogony-forms; (3) the trypaniform individuals in the body-cavity; and (4) the similar forms in the salivary glands. I feel it incumbent upon me to state that in my opinion the encapsuled forms are merely resting stages of rounded or crithidial forms, the interpretation of which as zygotes is a pure assumption, and that the so-called schizogony-forms have nothing at all to do with the life-cycle of Schizotrypanum, but appear to be merely parasitic organisms of the nature of yeasts from the intestine of the insect. In justice to the author, however, it should be mentioned that he does not regard his observations on the life-cycle in the invertebrate as in any way final, and considers that many points remain to be further investigated.

The memoir of Chagas contains a great number of very interesting observations to which space does not permit of further reference. We may direct attention especially to his experiments on the variations in the virulence of the parasite as the result of passage through different vertebrate hosts. The whole work is an exceedingly important contribution to our knowledge of the trypanosomes, and we desire to congratulate both the author and the Instituto Oswaldo Cruz on a great achievement.

E. A. MINCHIN.

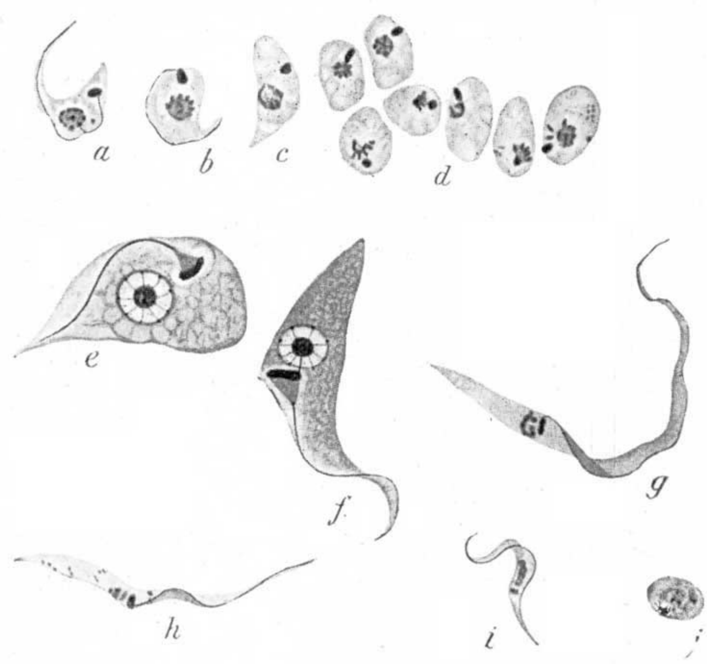

FIG. 3.—*a–j*, Phases of *Schizotrypanum cruzi* in the bug, *Conorhinus megistus*. *a*, *b* and *c*, forms transitional from the ordinary trypanosomes to the rounded forms; *d*, clump of rounded forms; *e* and *f*, change of rounded into crithidial forms; *g* and *h*, crithidial forms; *i*, trypaniform type from the salivary glands; *j*, encapsuled form from intestine.

TIDAL RESEARCHES.[1]

THE collection of data as to high and low water at various ports and the investigation of tidal currents present arduous tasks, and amongst those who have devoted themselves to these subjects Dr. J. P. van der Stok occupies a distinguished position. It is due to him that our knowledge of the tides of the Dutch East Indies rivals that furnished by our own admirable survey of India. He is an ardent adherent of the harmonic notation, and in the paper of which we now give an account he tabulates the principal tidal constants for no fewer than 138 ports in the Dutch Indies. To the best of my belief this immense mass of data has been collected and reduced through his own personal initiative.

This pamphlet gives an account of the theory on which harmonic analysis is based, but it is to be regretted, at least by all but his own fellow-countrymen, that it should have been written in his own language. Of course, the language is immaterial as regards the tables of constants, but it may prove an obstacle to those who desire to understand the other interesting points treated by the author.

Dr. van der Stok summarises his results in the form of co-tidal charts for the tract of ocean extending from the Malay Peninsula to New Guinea. The first of these exhibits the march of the principal lunar semidiurnal tide M_2. It appears that there is a point towards the south-eastern end of Sumatra at which the wave divides, one portion travelling north-west and the other eastward along the south coast of Java. Along the north-eastern coast of Sumatra, past Singapore, the wave travels in the opposite direction, namely, towards the south-east. It is met by a wave which travels westward and south-westward along the southern and northern coasts of Borneo, and westward along the northern coast of Java. Thus, in contrast with the divergence of the tide-wave off the south of Sumatra, there is a convergence from all sides towards a point midway between Sumatra and Borneo. Eastward of Borneo, in the direction of New Guinea, the general trend of the wave is northward.

The second of these co-tidal charts is, I believe, unique in that it exhibits the progress of the diurnal tide K_1.[1] The path of this wave exhibits a considerable resemblance to that pursued by the semidiurnal wave, but it differs in the fact that it seems to approach the south coast of Java from the south, and thus the line of advance is from the south throughout the whole tract extending from the southern extremity of Sumatra to New Guinea.

I do not think that any previous investigator has attempted to draw a diurnal co-tidal chart. In the north Atlantic the diurnal tide is insignificant in amount and imperfectly known, but I think it might be possible to construct a similar chart for the coasts of India; I am not aware, however, that any such attempt has ever been made.

At the present time there are only three tide-predicting instruments in existence, namely, those in England, France, and the United States; but I have reason to know that a fourth is being constructed for another Government. Without the aid of such an instrument, tidal prediction is notoriously very laborious, and any process which may render predictions easier is very welcome. I have myself shown how numerical predictions may be made, but the preliminary computations are very laborious and tedious, although when the requisite tables are once formed it is easy and short to make a prediction.[2] But this method does little to facilitate the computation of a tide curve for a given place and given day direct from the harmonic constants. Now Dr. van der Stok pro-

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[1] "Elementaire Theorie der Getijden—Getij-Constanten in den Indische Archipel." (K. Nederlandsch Meteorologisch Instituut, No. 102, 1910.)

[1] There is a short discussion of the diurnal tides in Harris's "Manual of Tides," part iv. A, p. 660.

[2] Phil. Trans., clxxxii. A, p. 169, or vol. i. of my "Scientific Papers."